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U.S. DEPARTMENT OF COMMERCE
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CONTENTS

ABSTRACT		1
1.	INTRODUCTION	1
2.	CLASSIFICATION RULES	2
3.	APPLICATION OF RULES TO FACE 1970 THROUGH 1978 DATA	4
4.	SUMMARY AND CONCLUDING REMARKS	4
5.	ACKNOWLEDGMENTS	5
6.	REFERENCES	5

CLASSIFICATION OF METEOROLOGICAL RADAR ECHOES BY THEIR STATE OF MOTION DURING FACE 1970 THROUGH 1978 – PROCEDURES AND RESULTS

Francis J. Merceret,[1] Ronald L. Holle, and John B. Cunning

ABSTRACT. A procedure for the classification of radar meteorological echoes according to their state of motion is described. The procedure applies a set of objective rules for interpreting radar film. The eight rules and the reasons for their formulation are presented. The results of the application of this scheme to radar data from operational days during the Florida Area Cumulus Experiment (FACE) for 1970 to 1978 are presented, discussed, and compared with the results from the previous procedure of classification.

1. INTRODUCTION

The Florida Area Cumulus Experiment (FACE) is a program designed to determine whether dynamic cloud seeding methods can be used to augment convective precipitation over 1.3×10^4 km^2 in south Florida (fig. 1). The program has been described in detail by Woodley and Sax (1976). Analysis of FACE rainfall has relied heavily on radar, and several covariates of precipitation have been used in the analysis.

Echo motion determined from the radar images (Biondini, 1977; Woodley et al., 1977) is important because a significant physical mechanism may be dynamic coupling of the clouds' internal motions with the boundary layer. Such coupling is believed to be affected by upper- and mid-level wind-induced advection, but not by echo motion caused by propagation growth in a preferred direction. Propagation does not involve motion of the convective cells relative to the surface, but rather the development of new cells. (A detailed description of the physics and significance of echo motion is beyond the scope of this report.) Determination of radar echo motion necessitates a reliable, rational, and repeatable method. This paper describes such a method.

Before 1978 echo motion classification was subjective and uneven. There were no explicit criteria, except that propagation was not considered motion. All days had to be designated as either "motion" or "no-motion." Different people did the classification in different years. Both the mandatory bimodal classification and the lack of objective criteria had been criticized informally, and FACE project scientists decided in 1978 to revise the procedure. Effective algorithms for automatic classification were much too time-consuming for existing resources, so a set of objective rules was devised. The new system has motion and no-motion categories and a third category called "other" to describe certain situations that do not fit neatly in the other two. As anticipated, some FACE days from 1970-1977 have been reclassified; 1978 days were all classified by the new system. The classification of all FACE randomized ("GO") days under both schemes is listed in section 3.

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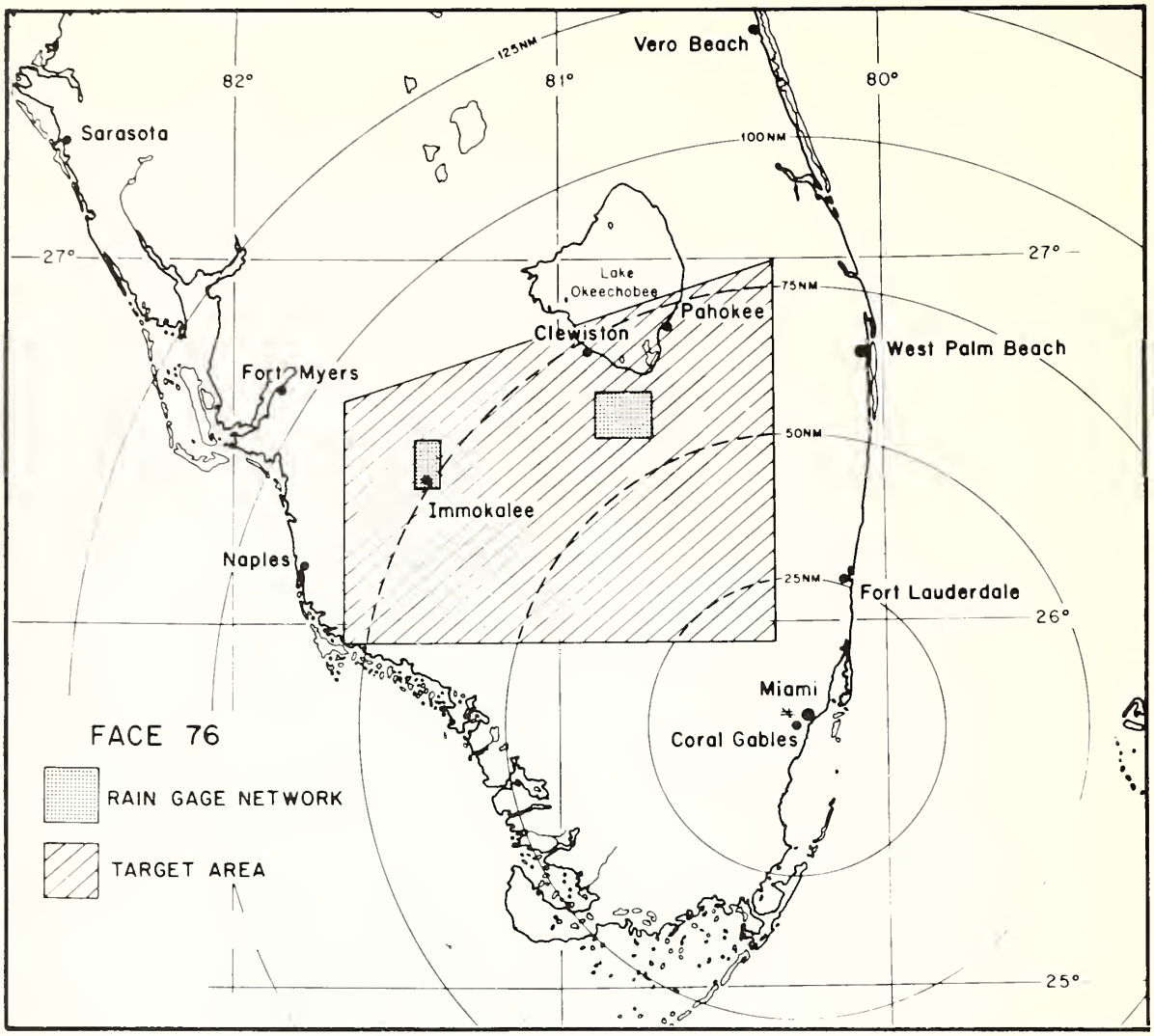

Figure 1.--The FACE 1970 through 1978 seeding target area in south Florida is shown by the hatched area northwest of Miami. The WSR-57 radar is at Coral Gables. The rain gage network area changes annually.

2. CLASSIFICATION RULES

Days were classified as motion, no-motion, and other, on the basis of observations from the Miami National Weather Service WSR-57 radar. Data were in the form of 35-mm black-and-white film; frames were taken at 5-min intervals. The radar film was viewed on a 35-mm stop-motion projector with variable speed control that was set at 15 frames per second. There are eight classification rules, which are presented below and explained. They are given in exactly the same order and wording used by the classifiers when the data presented in this paper were processed.

Rule 1: If an echo is in the analysis area at any time during its lifetime, its whole path may be used. No echoes may be used that fail to enter the analysis area. The analysis area is the northwest quadrant of the Miami WSR-57 radar out to 100 nautical miles.

Rule 2: Time [data period] of analysis is from 1600 to 0200 UT only.

Rule 3: Echo motions must be general and somewhat uniform in direction for the day to qualify as a motion day. Echoes must not be moving (except by propagation) to qualify the day as a no-motion day. Days on which echoes move in diverse directions, or on which some clouds move and some do not, will be classified separately. Direction changes with time do not make the motion nonuniform if all echo motions change together.

Rule 4: On days in which the amount of echo motion changes with time, the day shall be classified as motion if a major portion of the analysis period qualifies for motion classification. It shall be classified as no-motion if a major portion of the analysis period qualifies for no-motion classification. If neither mode is clearly predominant, the day shall be separately classified. When there is doubt as to classification under this rule, emphasis should be given to the status of motion from 1800 to 2200 UT.

Rule 5: Categories of motion status are motion, no-motion, and other. The criteria for motion and no-motion are described in Rules 1-4 above.

Rule 6: Days classified other shall be identified as to the reason for this classification. Reasons shall be selected from the following set:

a) Diverse direction or motion status as described in Rule 3.
b) Change of motion with time as described in Rule 4.
c) Insufficient echoes or poor data quality that precludes echo tracking.
d) Classifying personnel cannot agree on classification.

Rule 7: A form containing these columns shall be used:

Column 1: Date
Column 2: Category
Column 3: Remarks

The form shall contain the names of the classification personnel.

Rule 8: Instructions to the classification personnel shall include these rules and shall note that when category other is designated, the appropriate subcategory (i.e., a, b, c, or d) should be designated (e.g., other (b)). The comments column should be used to explain the classification more fully.

The reasons for the rules are the following:

Rules 1 and 2 determine the echoes to be used in the analysis and insure that different analysts use the same data. The northwest quadrant of the radar area was chosen for analysis because it consists mainly of the FACE seeding target area. The analysis time in Rule 2 includes the typical period when convection is seeded and rain volumes are calculated, since the statistical results of FACE are based on analysis of rainfall from first seed time to first seed plus 6 hours.

Rule 3 defines the motion and no-motion categories. Dynamic coupling of the clouds' internal motions with the boundary layer may be the physical mechanism that distinguishes motion from no-motion situations. The coupling may be weakened by advection induced by winds above the boundary layer, but it is not modified by echo growth, even in a preferred direction. Advection involves relative motion between the active cells of the convection and the surface, whereas addition of new cells alone does not. It is the relative motion that affects the dynamic coupling. Note that echoes that propagate, but are not advected in bulk, are considered to be not in motion for purposes of this rule. Propagation and advection are distinguished in the radar images subjectively by behavior of the echoes with time. If echoes enlarge in a preferential direction with identifiable elements remaining fixed, then propagation is taking place. If the echoes as a whole move, propagation is not occurring.

Rule 4 refines Rule 3 for situations where the echo motion changes with time. The status of motion from 1800 to 2200 UT is important because most FACE activities, e.g., seeding, took place during this period.

Rules 5 and 6 define the category other and are self-explanatory.

Rules 7 and 8 are administrative rules to assure strict compliance with other rules and adequate documentation for each classification.

Rules 1 through 8 were established and agreed upon by the authors and other FACE personnel before the classification began.

3. APPLICATION OF RULES TO FACE 1970 THROUGH 1978 DATA

Application of these rules to FACE data from 1970 through 1978 has resulted in a satisfactory definition of all cases. The rules, then, seem to provide a good framework in which to judge echo motion. The authors examined radar data for all GO days from FACE 1970 through 1978. A GO day is a randomized experimental day, which may be either seeded or unseeded. The two types of GO days are an A day, on which fewer than 60 flare drops are attempted, and a B day, on which 60 or more drops are attempted (Woodley et al., 1977; Woodley and Sax, 1976). The category decision for each day was agreed upon after discussion. If agreement could not be reached the category other (d) was selected. Tables 1 through 6 present echo motion results by data for GO days. Assessment of motion type for the new category was made by the authors using the rules described in section 2. Classification of motion type for the former category is available in various FACE project reports, summaries, and data listings; in this classification system GO days were either motion or no-motion. The comments in tables 1 through 6 apply to the new category only.

In tables 1 and 2, it is apparent that 1970 and 1971 film data were somewhat different from that of other years. During 1970 and 1971, the film covered a 200-nmi range, while in all other years it had a maximum range of 125 nautical miles. This resulted in a smaller FACE target area on the picture. Also during these 2 years, the Miami radar had no Video Integrator Processor (VIP) capability, so the intensity of radar signals was not apparent. Analysis was much more difficult in 1970 and 1971, without VIP. From 1973 through 1978 there were centers and smaller features on radar that could be identified and tracked, unlike the more diffuse echoes in 1970 and 1971. In table 6 there are no data listed under the former category, since the classification system given in section 2 was the only technique used at the end of FACE 1978.

The numbers of changes between former and new categories of echo motion are given in table 7. The table shows that there were 22 changes in the 99 cases considered. When one considers that film data from 1970 and 1971 were more difficult to use, the agreement is quite good. This agreement lends confidence to the repeatability of the results, even when the informal technique is considered. If one removes the 12 changes to other, which was a nonexistent category under the former scheme, the overall result is 10 changes out of 87 cases, or 11%. From 1973 to 1976, the change rate (excluding changes to other) is only 8 of 79, or 10%. It should be noted that on 4 days there was insufficient or no film for determining echo motion with the new method (although the radar was operating), and these days were classified as other. The former classification had found echo motion from data and observations other than film; these sources were not used for the new category results.

4. SUMMARY AND CONCLUDING REMARKS

A set of objective rules for the classification of radar meteorological echoes by their status of motion has been presented. Application of the scheme to FACE data from 1970 through 1978 shows that the system covers all classes of observed phenomena and produces fairly uniform acceptable results. This procedure also provides a satisfactory method for using echo motion to stratify precipitation statistics. The addition of a category for other preserves the purity of the motion and no-motion categories as covariates by removing doubtful cases. Some rewording and reordering of the rules might make them clearer or more concise, but their basic structure should be maintained for the duration of FACE.

5. ACKNOWLEDGMENTS

The authors thank John Flueck of Temple University, William Woodley of NHEML, Robert Sax of the Joseph Oat Corporation, and Joanne Simpson of the National Aeronautics and Space Administration for their suggestions and encouragement during the development of the system described in this paper.

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Table 1.--Results of classification of radar echo motion by two methods for GO days, FACE 1970

Date	Julian day	Type of Go day	Category		Change	Comments
			New	Former		
29 June	180	B	Motion (N)	Motion (W)		No VIP, 200-nmi range film
30 June	181	B	Motion (NNE)	No-motion	X	No VIP, 200-nmi range film
2 July	183	B	Motion (E)	No-motion	X	No VIP, 200-nmi range film
7 July	188	B	Other (d)	No-motion	X	No VIP, 200-nmi range film; too complex, may be no-motion
8 July	189	B	No-motion	No-motion		No VIP, 200-nmi range film
18 July	199	B	No-motion	No-motion		No VIP, 200-nmi range film; sparse intermittent data

Table 2.--Results of classification of radar echo motion by two methods for GO days, FACE 1971

Date	Julian day	Type of Go day	Category		Change	Comments
			New	Former		
16 June	167	B	Motion (WSW)	Motion (WSW)		No VIP, 200-nmi range film; sparse echoes
1 July	182	B	Motion (SE)	Motion (ESE)		No VIP, 200-nmi range film
12 July	193	B	Other (a)	No-motion	X	No VIP, 200-nmi range film; converging sea breeze lines
13 July	194	B	Other (b)	Motion (E)	X	No VIP, 200-nmi range film; SE until 2300 UT, then still
14 July	195	B	Other (d)	Motion (E)	X	No VIP, 200-nmi range film; chaotic; maybe weak W with strong propagation
15 July	196	B	Motion (S)	Motion (SSE)		No VIP, 200-nmi range film

Table 3.--Results of classification of radar echo motion by two methods for GO days, FACE 1973

Date	Julian day	Type of Go day	Category		Change	Comments
			New	Former		
5 July	186	A	Motion (W)	Motion (WSW)		
7 July	188	B	Motion (NW)	No-motion	X	Later from N
16 July	197	B	No-motion	No-motion		
17 July	198	B	Motion (E)	Motion (E)		
20 July	201	B	Motion (ESE)	Motion (E)		
25 July	206	B	Motion (NE)	Motion (E)		Weak; accelerates later to SSW
30 July	211	A	Motion (S)	Motion (S)		
6 August	218	B	No-motion	No-motion		
8 August	220	A	Motion (NE)	Motion (ENE)		Later ENE
9 August	221	B	Other (b)	Motion (ENE)	X	Still to 2200 UT; then motion from NE
12 August	224	A	Motion (ESE)	Motion (E)		
13 August	225	A	Motion (SE)	Motion (E)		
22 August	234	B	Motion (W)	Motion (W)		
25 August	237	B	Motion (SE)	Motion (SSE)		
27 August	239	B	Motion (ENE)	Motion (ENE)		
28 August	240	B	Motion (NNE)	Motion (NE)		
9 Sept.	252	B	No-motion	Motion (WSW)	X	
12 Sept.	255	A	No-motion	Motion (WNW)	X	Few echoes

Table 4.--Results of classification of radar echo motion by two methods for GO days, FACE 1975

Date	Julian day	Type of Go day	Category		Change	Comments
			New	Former		
16 June	167	A	No-motion	Motion (SE)	X	A typical chaotic propagation
18 June	169	A	Motion (ESE)	Motion (ESE)		
21 June	172	B	No-motion	No-motion		
22 June	173	B	Motion (E)	Motion (E)		Cirrus from W
24 June	175	B	Motion (NNW)	No-motion	X	Slow
25 June	176	B	Motion (W)	Motion (W)		Slow; later from NW
27 June	178	B	Motion (SW)	Motion (WSW)		
28 June	179	A	Motion (WSW)	Motion (WSW)		
30 June	181	B	No-motion	No-motion		Systematic propagation from NE TO SW
7 July	188	A	Motion (SW)	Motion (WSW)		Film double-exposed; difficult to analyze
9 July	190	B	Motion (S)	Motion (S)		Film double-exposed; direction imprecise
16 July	197	B	Motion (SE)	Motion (SE)		Fill 2200 to 0200 UT only
18 July	199	B	Motion (SE)	Motion (E)		Superimposed on propagation from E
19 July	200	B	Motion (SE)	Motion (ESE)		SE to SSE
20 July	201	B	Motion (SSE)	Motion (S)		
23 July	204	B	Motion (ENE)	Motion (E)		
24 July	205	B	Motion (ENE)	Motion		Slow
25 July	206	A	No-motion	No-motion		Film begins 1800 UT; rapid random propagation
26 July	207	B	Motion (SE)	Motion (E)		Slow
29 July	210	B	Other (a)	Motion (SSW)	X	West half from SW; east half from SE
30 July	211	B	Motion (E)	Motion (E)		
13 August	225	B	No-motion	No-motion		Active propagation
15 August	227	B	Motion (ESE)	Motion (ESE)		
16 August	228	B	Other (c)	Motion (E)	X	Film 1600 to UT only; no echoes
17 August	229	A	Other (c)	No-motion	X	No film
19 August	231	B	No-motion	No-motion		Radar intermittent; changes to ENE after 0000 UT
25 August	237	B	Other (c)	Motion (E)	X	No film
28 August	240	B	Motion (NE)	Motion (ene)		ENE later
3 Sept.	246	A	Motion (SE)	Motion (SE)		
11 Sept.	254	B	Motion (E)	Motion (E)		
12 Sept.	255	B	Motion (e)	Motion (E)		Slow
14 Sept.	257	A	Motion (NE)	Motion (E)		E later

Table 5.--Results of classification of radar echo motion by two methods for GO days, FACE 1976

Date	Julian day	Type of Go day	Category		Change	Comments
			New	Former		
3 June	155	B	Motion (SSW)	Motion (S)		
4 June	156	A	Other (c)	Motion (SW)	X	No film 1600 to 0400 Ut
6 June	158	B	No-motion	No-motion		Maybe weak NE hidden in propagation
8 June	160	B	Motion (SW)	Motion (W)		
25 June	177	A	Motion (ESE)	Motion (W)		
26 June	178	B	Motion (SE)	Motion (E)		
27 June	179	A	Motion (ENE)	Motion (E)		
28 June	180	B	Other (a,b)	No-motion	X	N-fixed; W-still, then motion; S-motion, then still
29 June	181	B	No-motion	No-motion		
30 June	182	B	Motion (SSW)	No-motion	X	Slow
5 July	187	B	Motion (SE)	Motion (S)		
6 July	188	B	Motion (SE)	Motion (SSE)		
11 July	193	A	Motion (SW)	Motion (S)		AP in NW target area; late-stationary or NW
14 July	196	A	Other (c)	Motion (W)	X	One small brief echo only
16 July	198	B	No-motion	No-motion		Much AP; fuzzy echoes; may be slow hidden motion
17 July	199	B	No-motion	No-motion		
18 July	200	B	No-motion	No-motion		
19 July	201	A	Motion (SE)	Motion (SE)		
20 July	202	B	Motion (ESE)	Motion (SE)		
21 July	203	B	Motion (NE)	Motion (ENE)		
23 July	205	B	Motion (SE)	Motion (ESE)		
24 July	206	B	Motion (SE)	Motion (SE)		
25 July	207	B	Motion (ESE)	Motion (ENE)		Turning to NE
26 July	208	B	Motion (ENE)	Motion (E)		
30 July	212	A	Motion (E)	Motion (E)		Quite weak
31 July	213	B	No-motion	No-motion		
5 August	218	B	No-Motion	No-Motion		
6 August	219	B	Motion (N)	No-motion	X	
10 August	223	A	Motion (SSW)	Motion (S)		No film after 2100 UT
11 August	224	A	Motion (ENE)	Motion (E)		Fast; no film before 1900 UT
15 August	228	B	No-motion	No-motion		Few echoes
16 August	229	B	No-motion	No-motion		Radar intermittent
21 August	234	B	Motion (SW)	Motion (S)		
22 August	235	A	Motion (NW)	Motion (NW)		
26 August	239	B	Motion (ENE)	Motion (E)		
30 August	243	B	Motion (E)	Motion (ENE)		

Table 6.--Results of classification of radar echo motion with new method for GO days, FACE 1978

Date	Julian day	Type of GO day	New Category	Comments
29 June	180	B	Motion (E)	
30 June	181	B	Other (a)	Center-still; extreme N and S-from E
1 July	182	B	No-motion	
2 July	183	B	Motion (WNW)	
3 July	184	B	Motion (SW)	Weak
5 July	186	A	Motion (SW)	Much AP
10 July	191	B	Motion (SE)	
18 July	199	A	Motion (WSW)	Heavy AP and anvil rain
25 July	206	B	Motion (SE)	Short-lived echoes
29 July	210	B	Motion (W)	Propagation in same direction also
4 August	216	B	Motion (E)	
5 August	217	A	Motion (SE)	Slow
10 August	222	B	Motion (SE)	
11 August	223	B	Motion (SSE)	Turning to SSW
12 August	224	B	Other (a,b)	Chaotic, diverse in space and time
13 August	225	B	Motion (SSE)	Slow
14 August	226	B	Motion (E)	
16 August	228	B	Motion (ESE)	A few stationary echoes
17 August	229	B	Motion (SE)	
18 August	230	A	No-motion	
29 August	241	B	Motion (SE)	A few stationary echoes

Table 7.--Summary of changes in classification of echo motion

Year	Total GO days	Changes			Total changes	Percent total changes
		To motion	To other	To no-motion		
1970	6	2	1	0	3	50
1971	6	0	3	0	3	50
1973	18	1	1	2	4	22
1975	32	1	4	1	6	19
1976	37	3	3	0	6	16
All years	99	7	12	3	22	22

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